RESEARCH DEPARTMENT

# Diurnal and seasonal variations in tropospheric propagation characteristics

RESEARCH REPORT No. RA-11

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

# DIURNAL AND SEASONAL VARIATIONS IN TROPOSPHERIC PROPAGATION CHARACTERISTICS

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for Head of Research Department

This Report uses SI units in accordance with B.S. document PD 5686.

Research Report No. RA-11

# DIURNAL AND SEASONAL VARIATIONS IN TROPOSPHERIC PROPAGATION CHARACTERISTICS

TABLEAU III

VALEURS MEDIANES OBSERVEES

(Affaiblissement de transmission, L (db))

TABLE III

OBSERVED MEDIAN VALUES

(Transmission loss, L (db))

CUADRO III

VALORES MEDIANOS OBSERVADOS

(Pérdidas de transmisión, L (db))

Distance (km)
Distancia (km) 113

Frequency (Mc/s)
Frequence (MHz) 254.6
Frecuencia (Mc/s)

Path designator
Symbole du trajet JAP - 5
Simbolo del trayecto

For the month of
Pour le mois de V
Por el mes de

Year
Année 1958
Año

| Date | Heure de l'observation (Heure locale) | | | | | | | | | Hour of observation (Local time) | | | | | | | | | Hora de la observación (Hora local) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Día | 00-01 | 01-02 | 02-03 | 03-04 | 04-05 | 05-06 | 06-07 | 07-08 | 08-09 | 09-10 | 10-11 | 11-12 | 12-13 | 13-14 | 14-15 | 15-16 | 16-17 | 17-18 | 18-19 | 19-20 | 20-21 | 21-22 | 22-23 | 23-24 |
| 1 | 142.1 | 142.1 | 138.3 | 137.3 | 142.1 | 138.3 | 135.3 | 133.8 | 136.3 | 133.6 | 129.3 | 129.2 | 129.8 | 131.3 | 135.0 | 131.3 | 127.5 | 124.9 | 124.3 | 126.8 | 128.2 | 122.9 | 123.0 | 124.0 |
| 2 | 121.0 | 123.2 | 123.8 | 118.3 | 124.9 | 129.4 | 138.6 | 138.3 | 135.3 | 135.7 | 135.4 | 127.8 | 128.3 | 130.5 | 130.9 | 129.9 | 126.8 | 124.1 | 119.6 | 115.9 | 118.5 | 124.2 | 123.0 | 120.7 |
| 3 | 118.4 | 123.0 | 128.7 | 127.5 | 124.1 | 120.6 | 123.3 | 129.5 | 133.5 | 124.7 | 115.3 | 122.8 | 140.6 | 140.3 | 139.6 | 132.3 | 134.0 | 136.1 | 136.0 | 138.0 | 138.0 | 137.5 | 136.4 | 135.2 |
| 4 | 133.5 | 133.8 | 136.9 | 138.1 | 134.6 | 138.1 | 134.5 | 133.8 | 137.6 | 129.5 | 124.4 | 120.0 | 120.5 | 122.6 | 118.9 | 125.0 | 122.3 | 124.6 | 120.6 | 125.3 | 131.3 | 133.6 | 133.9 | 134.5 |
| 5 | 133.7 | 134.2 | 134.7 | 135.3 | 135.4 | 135.3 | 135.7 | 136.9 | 137.6 | 136.5 | 136.0 | 135.2 | 134.4 | 132.5 | 133.0 | 133.0 | 130.8 | 127.3 | 128.2 | 129.0 | 131.7 | 136.9 | 137.1 | 137.7 |
| 6 | 147.0 | 132.8 | 135.0 | 146.6 | 146.0 | 129.0 | 135.9 | 133.5 | 126.9 | 133.0 | 134.6 | 136.8 | 128.0 | 124.1 | | | | | 133.1 | 132.1 | 132.1 | 126.8 | 127.6 | 128.3 |
| 7 | 136.3 | 140.9 | 138.2 | 148.0 | 147.1 | 133.5 | 132.0 | 131.7 | 131.0 | 131.6 | 131.1 | 131.0 | 131.6 | 132.8 | 133.9 | 133.9 | 133.0 | 132.4 | 133.4 | | | | | |
| 8 | | | | | | | | | | 133.9 | 131.6 | 134.1 | 136.2 | 137.1 | 131.9 | 128.2 | 128.0 | 128.1 | 129.4 | 126.9 | 124.6 | 125.0 | 122.6 | 126.0 |
| 9 | 130.4 | 131.9 | 131.2 | 128.5 | 129.6 | 147.3 | 129.6 | 121.5 | 142.2 | 121.0 | 119.0 | 118.0 | 126.0 | 131.8 | 133.3 | 134.1 | 129.4 | 130.5 | 133.2 | 126.0 | 130.0 | 130.5 | 133.8 | 135.3 |
| 10 | 136.2 | 134.9 | 135.4 | 137.2 | 133.4 | 129.8 | 129.9 | 131.5 | 127.8 | 125.9 | 125.1 | 121.0 | 124.2 | 122.6 | 130.5 | 129.8 | 128.0 | 124.9 | 128.7 | 131.4 | 132.0 | 130.5 | 134.1 | 135.4 |
| 11 | 136.2 | 136.6 | 136.7 | 137.5 | 137.2 | 137.5 | 136.7 | 136.9 | 138.5 | 135.4 | 136.7 | 139.6 | | 143.1 | 143.7 | | 144.8 | 147.7 | 141.1 | 142.7 | 138.0 | 137.3 | 140.2 | 137.3 |
| 12 | 137.0 | 137.6 | 137.2 | 137.6 | 138.3 | 137.8 | 137.6 | 137.6 | 136.9 | 137.3 | 137.4 | 136.8 | 136.8 | 136.3 | 136.5 | 136.3 | 136.0 | 137.4 | 138.3 | 138.6 | 139.4 | 139.6 | 139.9 | 140.0 |
| 13 | 140.3 | 138.9 | 138.5 | 138.4 | 138.5 | 138.5 | 137.9 | 139.4 | 139.7 | 140.1 | 140.1 | 139.6 | 134.7 | 132.8 | 132.6 | 130.2 | 141.0 | 141.0 | 140.7 | 140.2 | 140.2 | 139.3 | 138.7 | 138.1 |
| 14 | 132.6 | 120.5 | 119.2 | 117.4 | 119.8 | 123.1 | 127.2 | 124.0 | 124.1 | 126.9 | 133.5 | 133.5 | 131.0 | 140.1 | 138.4 | 134.9 | 136.2 | 147.5 | 147.5 | 147.9 | 147.5 | 147.8 | 138.7 | 137.1 |
| 15 | 135.8 | 135.4 | 136.0 | 137.8 | 137.8 | 137.8 | 138.5 | 138.5 | 138.0 | 138.3 | 137.9 | 137.9 | 137.9 | 139.2 | 144.6 | 143.9 | 144.4 | 140.8 | 140.0 | 137.1 | 131.9 | 130.7 | 127.0 | 129.8 |
| 16 | 134.2 | 135.2 | 136.4 | 135.4 | 136.1 | 133.6 | 133.7 | 134.1 | 137.1 | 132.1 | 132.6 | 133.8 | 133.9 | 137.1 | 137.1 | 133.9 | 134.9 | 134.6 | 136.4 | 133.9 | 133.9 | 133.8 | 131.2 | 134.5 |
| 17 | 137.0 | 137.5 | 137.2 | 137.5 | 138.2 | 138.8 | 138.7 | 138.7 | 137.2 | 138.0 | 138.5 | 139.6 | 139.9 | 139.1 | 140.7 | 135.6 | 133.9 | 127.8 | 124.1 | 128.2 | 123.9 | 125.5 | 123.0 | 128.2 |
| 18 | 133.1 | 127.7 | 122.9 | 118.6 | 123.1 | 121.5 | 113.1 | 104.1 | 117.9 | 120.8 | 113.5 | 108.6 | 106.2 | 108.6 | 116.9 | 125.5 | 126.3 | 130.3 | 120.9 | 128.4 | 124.5 | 120.6 | 134.7 | 129.2 |
| 19 | | 123.6 | 130.0 | 132.1 | | | 133.0 | 129.3 | 137.4 | 138.1 | 140.7 | 140.5 | 139.4 | 139.4 | 139.4 | 140.0 | 139.7 | 139.3 | 139.3 | 139.2 | 138.6 | 137.8 | 135.4 | 134.7 |
| 20 | 131.5 | 133.6 | 133.4 | 132.5 | 134.4 | 138.4 | 136.7 | 138.4 | 135.9 | 140.1 | 137.9 | 136.3 | 133.5 | 133.2 | 133.1 | 130.6 | 133.6 | 134.3 | 127.8 | 127.8 | 128.3 | 133.5 | 131.5 | 130.8 |
| 21 | 129.3 | 131.4 | 132.1 | 130.6 | 129.6 | 121.8 | 122.1 | 118.8 | 118.0 | 118.0 | 123.6 | 129.8 | 123.1 | | 139.4 | 140.7 | 132.2 | 129.0 | 128.4 | 126.7 | 129.5 | 133.1 | 129.5 | 132.5 |
| 22 | 132.1 | 131.9 | 133.4 | 132.9 | 132.2 | 132.1 | 127.6 | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | |

*Fig. 1 - Example of transmission loss tabulations as presented in ITU handbook*

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# DIURNAL AND SEASONAL VARIATIONS IN TROPOSPHERIC PROPAGATION CHARACTERISTICS

SUMMARY

*In the channel sharing problems associated with broadcast planning at v.h.f. and u.h.f. it is usually assumed that interference from co-channel stations occurs randomly in time. This implies that there is equal probability of occurrence of the meteorological conditions giving rise to abnormal tropospheric propagation at any time of day or any season of the year. In this report the results of previous measurements are re-analysed to assess the validity of this assumption. It is deduced that both diurnal and seasonal trends occur, and that these trends are different for propagation over land and sea paths.*

## 1. INTRODUCTION

In planning television broadcasting transmitter networks in the v.h.f. and u.h.f. bands, consideration must be given to the probability of interference due to abnormal tropospheric propagation of signals transmitted from distant co-channel stations. Estimates of the probability of such interference are generally based on the well-known CCIR field-strength/distance curves[1] for tropospheric propagation in these bands. These curves have been compiled from the results of field-strength recordings over numerous paths, obtained by various organizations, including the BBC. The majority of these recordings have been made over prolonged periods with daily transmission schedules of from 0800 or 0900 to 2300 or 2400 hours, and the curves therefore represent probabilities related to this daily period. Any regular diurnal trend in propagation characteristics will produce a resultant variation in field-strength probabilities throughout the day. This report re-analyses the available data to assess the significance of any such diurnal trends. Seasonal trends are also discussed.

## 2. EXPERIMENTAL RESULTS

Data for this investigation are available from three independent sources:-

(i) The ITU publication[2] - 'CCIR propagation data obtained in radio-relay systems'

(ii) Previous tropospheric measurement programmes at v.h.f. and u.h.f. undertaken by the BBC[3,4,5,6,7,8] between the years 1954 and 1965

(iii) Current BBC tropospheric measurement programmes.

### 2.1. CCIR Propagation Data

#### 2.1.1. CCIR Results

In conformity with a decision taken at the Interim Meeting of Study Group V Geneva, 1962, the CCIR Secretariat requested Administrations to furnish data on transmission loss in systems using the tropospheric scatter mode of propagation. This request is also dealt with in CCIR Report 241[9]. A large amount of data relating to CCIR Study Programmes 185A(V) and 185B(V) was received in response to the request and has been published[2].

Measurements of field strength obtained over numerous paths* at various frequencies in the v.h.f., u.h.f. and s.h.f. bands are tabulated in terms of median values for standard periods of one hour; more specifically the tables give the median hourly transmission loss (m.h.t.l.) pertaining to each hour of the day for each day of the month, for whatever total period such results may be available. This period will generally be of several months duration. An example of the form of tabulation employed is represented in Fig. 1.

* Unfortunately virtually all the available data refers to paths in the U.S.A. or Japan. Also many of the tables refer to measurement periods too short to represent a suitable statistical sample.

*TABLE 1*

| Curve of Fig. 2 | CCIR path coding | Country | Type of path | Path length (km) | Freq. (MHz) | Approx. duration (days) | Months | Remarks |
|---|---|---|---|---|---|---|---|---|
| (a) (i) | JAP 5 | Japan | Sea | 113 | 254 | 80 | October to August | Simultaneous recordings over same path |
| (a) (ii) | JAP 6 | Japan | Sea | 113 | 970 | 75 | October to August | |
| (a) (iii) | JAP 12 | Japan | Sea | 300 | 487 | 80 | October to August | Simultaneous recordings over same path |
| (a) (iv) | JAP 13 | Japan | Sea | 300 | 1300 | 75 | October to August | |
| (b) | U.K. M-1 | Persian Gulf | Mixed land/sea | 135 | 80 | 160 | August to March | Tropical path not representative of U.K. |
| (c) (i) | U.S.A. 216 | U.S.A. (Illinois) | Land | 204 | 192 | 55 | Feb. and August | |
| (c) (ii) | JAP 7 | Japan | Land | 147 | 95 | 90 | April, Aug. to Oct., January | Same path |
| (c) (iii) | JAP 8 | Japan | Land | 147 | 209 | 110 | April, Aug. to Feb. | |
| (c) (iv) | U.S.A. 294 | U.S.A. (Colorado) | Land | 155 | 230 | 30 | March and August | |

The results obtained over nine such paths have been examined to assess whether any diurnal trends are apparent and details of these selected paths are given in Table 1. For each path the mean* value of the m.h.t.l. has been calculated from all data covering a particular time of day, i.e. for each individual hour of the day (for the hours between 0800 and 2400) over the whole period for which results are available. The deviations of these mean values of m.h.t.l. for each individual hour with respect to the overall mean value of m.h.t.l. for the total period of measurements are shown in Fig. 2. For convenience in indicating trends the results are shown as continuous curves drawn through the plotted points and the curves relating to transmission over land, sea and mixed land/sea paths have been shown separately. In Fig. 3(*a*) and 3(*b*) are plotted the corresponding results for the values of field strength exceeded on 10% of occasions (derived from the value of m.h.t.l. not exceeded in 10% of available samples). The results relate to one land path (JAP 8) and one sea path (JAP 5). The corresponding deviation of the mean values (from Fig. 2) are superimposed for the purpose of comparison.

### 2.1.2. Discussion of CCIR Results

The results in the ITU handbook appear to be the only ones available tabulated in a form suitable for determination of diurnal variations.

* An exception to this occurs for the results of path U.K. M-1 which are quoted in terms of median values of m.h.t.l. since they are tabulated in this form in the ITU handbook. This may make a small difference to an analysis of diurnal variations.

Five features can be deduced from the results represented in Figs. 2 and 3.

(i) Path U.K. M-1 shows a much greater diurnal variation than any other path. This may be attributed to the extreme climatic conditions of the Persian Gulf, rendering this result unrepresentative of conditions in the temperate zone which includes the United Kingdom.

(ii) Comparison of results at different frequencies over identical paths shows no indication of frequency dependence.

(iii) None of the sea paths shows any significant diurnal variation in median hourly transmission loss.

(iv) All the land paths exhibit a diurnal variation with the median hourly values of field strength enhanced in the early morning and in the evening. The mean value from 1900 to 2400 is from 2½ to 3½ dB above the overall mean.

(v) A comparison of the curves in Fig. 3(*a*) indicates a greater diurnal variation in the values of field strength exceeded for 10% of the time than in the equivalent mean value over the same land path. This is not surprising as it is to be expected that any variation will be enhanced by any form of analysis which emphasizes the periods of abnormal propagation. The analysis for the sea path represented in Fig. 3(*b*) shows little daily variation even for the ratio exceeded on 10% of occasions.

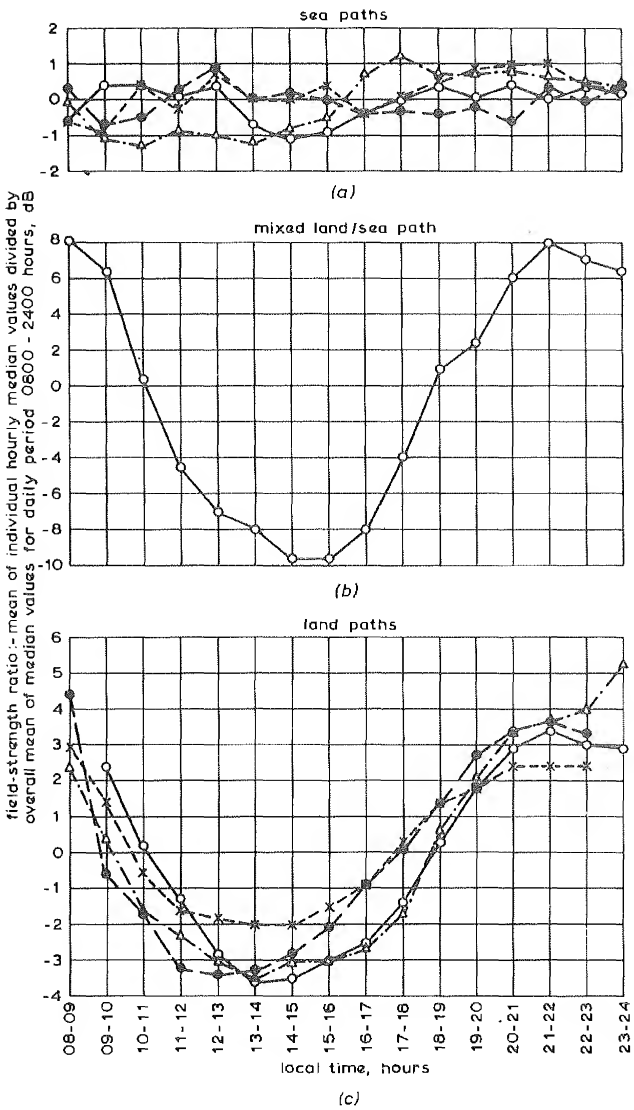



*Fig. 2 - Diurnal variations of hourly median field strength (CCIR data)*

| Sea Paths (a) | | Mixed Land/Sea Path (b) |
|---|---|---|
| —o— (i) JAP-5 | —●— (iii) JAP-12 | —o— U.K. M-1 |
| --x-- (ii) JAP-6 | -.-Δ-.- (iv) JAP-13 | |

Land Paths
(c)

—o— (i) U.S.A. 216 —●— (iii) JAP-8
--x-- (ii) JAP-7 -.-Δ-.- (iv) U.S.A. 294

## 2.2. BBC Propagation Data (1954 to 1965)

### 2.2.1. Results of Measurements Made Between 1954 and 1965

The results of previous series of propagation measurements over both land and sea paths[3,4,5,6,7,8] were analysed to provide field-strength probability distributions for both the normal daily transmission schedule, and for the evening period commencing at 1800 hours. The ratio of field strengths exceeded for specified time percentages in the evening period to those exceeded for the same time percentage in the overall period for these paths are given in Tables 2 and 3.

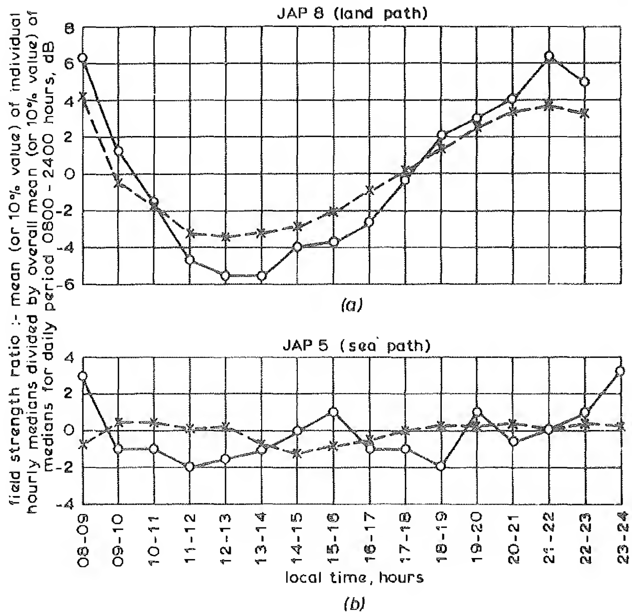



*Fig. 3 - Diurnal variation of hourly median field strength*

Comparison of mean values and values exceeded for 10% time

—o— Median exceeded on 10% of occasions
--x-- Mean of values (from Fig. 2)

### 2.2.2. Discussion of Previous BBC Results

The results detailed in Table 2 show that for overland paths there is a consistent tendency for the values of field strength exceeded for specified time percentages to be greater during the evening period than for the overall period. Furthermore, the magnitude of this excess increases as the time percentage value decreases (i.e. as the data becomes more dependent on abnormal conditions). The oversea measurements represented in Table 3 for Bands III and V show no such trends, although the Band IV results show a clearly defined enhancement of field strengths received in the evening period. With the exception of this Band IV oversea anomaly the results of these measurements confirm those of Section 2.1.

## 2.3. Current BBC Propagation Data

### 2.3.1. Results of Current BBC Propagation Experiments

Sections 2.1 and 2.2 have given quantitative results for diurnal variations of received field strength. To demonstrate this effect in pictorial fashion the results of recent measurements over various paths have been analysed for the months January to October 1966* in the form of a diagram

* February to October for the path Crystal Palace - Manningtree, the measurement programme at this site having been interrupted in January.

## TABLE 2

### RESULTS OF BBC MEASUREMENTS OVER LAND PATHS. TRANSMITTER AT PONTOP PIKE

*Ratio, in dB, of Field Strength Exceeded for Specified Time-Percentage of Evening Period to Field Strength Exceeded for Corresponding Time-Percentage of Overall Period*

| Receiving site | Distance (km) | Band III | | | | | Band IV | | | | | Band V | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0·5% | 1% | 2% | 5% | 10% | 0·5% | 1% | 2% | 5% | 10% | 0·5% | 1% | 2% | 5% | 10% |
| Dishforth | 85 | | | | | | | | | | | 2·0 | 3·0 | 3·0 | 2·5 | 1·5 |
| Moorside Edge | 140 | | | | | | | | | | | 1·5 | 1·5 | 1·5 | 1·0 | 0·5 |
| Ottringham | 172 | 5·0 | 3·0 | 2·5 | 1·5 | 1·0 | 6·5 | 5·5 | 5·0 | 3·0 | 2·0 | | | | | |
| Dorket Head | 214 | 3·0 | 3·5 | 2·5 | 1·0 | 0·5 | 3·5 | 3·0 | 1·0 | 0·5 | 0·5 | 1·5 | 1·5 | 1·5 | 1·5 | - |
| Mursley | 338 | 3·0 | 3·5 | 3·0 | 0·5 | 0·5 | 5·0 | 3·0 | 2·0 | 1·0 | 0·5 | 2·5 | 3·5 | 2·0 | - | - |
| Kingswood | 420 | 3·5 | 3·5 | 3·5 | 1·0 | 0 | 8·0 | 8·0 | - | - | - | 1·5 | 1·5 | 2·0 | - | - |
| Beddingham | 473 | 6·5 | 4·5 | 3·5 | 3·0 | 3·0 | 7·5 | 4·0 | - | - | - | 4·0 | 3·0 | - | - | - |
| Mean ratio for all sites:- | | 4·2 | 3·6 | 3·0 | 1·4 | 1·0 | 6·1 | 4·7 | 2·7 | 1·5 | 1·25 | 2·2 | 2·3 | 2·0 | 1·7 | 1·0 |

## TABLE 3

### RESULTS OF BBC MEASUREMENTS OVER SEA PATHS. TRANSMITTER AT SCHEVENINGEN

*Ratio, in dB, of Field Strength Exceeded for Specified Time-Percentage of Evening Period to Field Strength Exceeded for Corresponding Time-Percentage of Overall Period*

| Receiving site | Distance (km) | Band III | | | | | Band IV | | | | | Band V | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0·5% | 1% | 2% | 5% | 10% | 0·5% | 1% | 2% | 5% | 10% | 0·5% | 1% | 2% | 5% | 10% |
| Happisburgh | 198 | 2·0 | 3·0 | 2·0 | 0·5 | 0 | 1·0 | 1·0 | 1·5 | 1·5 | 4·0 | 0·5 | 1·0 | 1·0 | 3·0 | 2·0 |
| Flamborough | 365 | 0 | 0 | 0 | 0 | -0·5 | 1·5 | 3·0 | 3·0 | 4·5 | 2·0 | 1·0 | 2·0 | 2·5 | 3·0 | -1·0 |
| Newton | 543 | -2·0 | 2·0 | 4·0 | 3·0 | - | 2·0 | 2·0 | 3·0 | 5·0 | - | -1·0 | 0·5 | 1·0 | - | - |
| Bridge of Don | 690 | 0 | -0·5 | 0 | - | - | 3·5 | 5·0 | 5·0 | - | - | -2·5 | -0·5 | 0 | - | - |
| Lerwick | 950 | -1·5 | -5·0 | - | - | - | 8·5 | 9·0 | 5·0 | - | - | 4·0 | - | - | - | - |
| Mean ratio for all sites:- | | -0·3 | -0·1 | 1·5 | 1·2 | -0·25 | 3·3 | 4·0 | 3·6 | 3·7 | 3·0 | 0·4 | 0·75 | 1·1 | 3·0 | 0·5 |

## TABLE 4

### DETAILS OF TRANSMISSION PATHS EXAMINED IN FIGS. 4 AND 5

| Transmitter | Receiving site | Freq. (MHz) | Approx. path length (km) | Type of path | Field strength exceeded for specified time-percentage dB(μV/m) for 1 kW e.r.p. 5% | 1% | Period represented in field-strength/time percentage analysis |
|---|---|---|---|---|---|---|---|
| Crystal Palace | Manningtree | 573 | 100 | Land | 40·5 | 49·0 | May 1965 to August 1966 excluding Oct. 1965 to Jan. 1966 |
| Crystal Palace | Peterborough | 573 | 130 | Land | 21·0 | 35·0 | May 1965 to August 1966 |
| Crystal Palace | Tacolneston | 573 | 150 | Land | 25·0 | 42·5 | November 1965 to Sept. 1966 |
| Scheveningen | Gt. Baddow | 774 | 260 | Mixed land/sea | 21·0 | 33·0 | April 1965 to October 1966 |

showing the actual time of occurrence of high field-strengths. The method used was to obtain, for the chosen paths, the field-strength/time-probability distributions obtained over as long a recording period as possible. From these distributions the values were obtained of field strength (in dB($\mu$V/m) for 1 kW e.r.p.) exceeded for 1% and 5% of the time. These values, and details of the paths, are given in Table 4. The receiving aerial heights were all approximately 10 m a.g.l.

The diagram presented in Fig. 4 shows the times of occurrence of abnormal propagation conditions giving rise to field-strength values in excess of the specified levels. These levels (5% and 1% time) were selected as representing the range of time-percentage of particular interest for planning purposes in the u.h.f. broadcasting band. Where the field strength has not exceeded the lower level (5% time) during any day on any of the four transmission paths the line for that day is omitted from the diagram.

#### 2.3.2. Discussion of Results of Current Series of Measurements

Of the four paths investigated three are overland and the fourth (Scheveningen - Gt Baddow) is a mixed land/sea path. Since, however, the proportion of land is very small this latter path may be considered to be representative of an oversea path. An examination and comparison of the results given in Fig. 4 discloses the following obvious features:-

(i) There are several periods common to all paths during which prevailing anticyclonic conditions provide high field strengths. These periods are (a) January 5th to 9th (b) April 25th to May 2nd, (c) August 16th to 20th, (d) September 19th to 21st. Additionally high field strengths have persisted through much of June and July.

(ii) For both the land paths for which suitable data are available* the period January 5th to 9th is exceptional in that high field strengths persisted throughout the daily transmission period. This is shown in Fig. 5(*b*) which reproduces the recordings obtained on January 6th.

(iii) Apart from this exceptional period, only a very small proportion of the high field strength periods over land paths have occurred between the hours of 1100 and 1900. The highest field strengths tend to occur either at the start, or towards the end of the daily transmission schedule. This is shown most clearly during the period August 16th to 20th. Fig. 5(*a*) reproduces the recording obtained on August 18th.

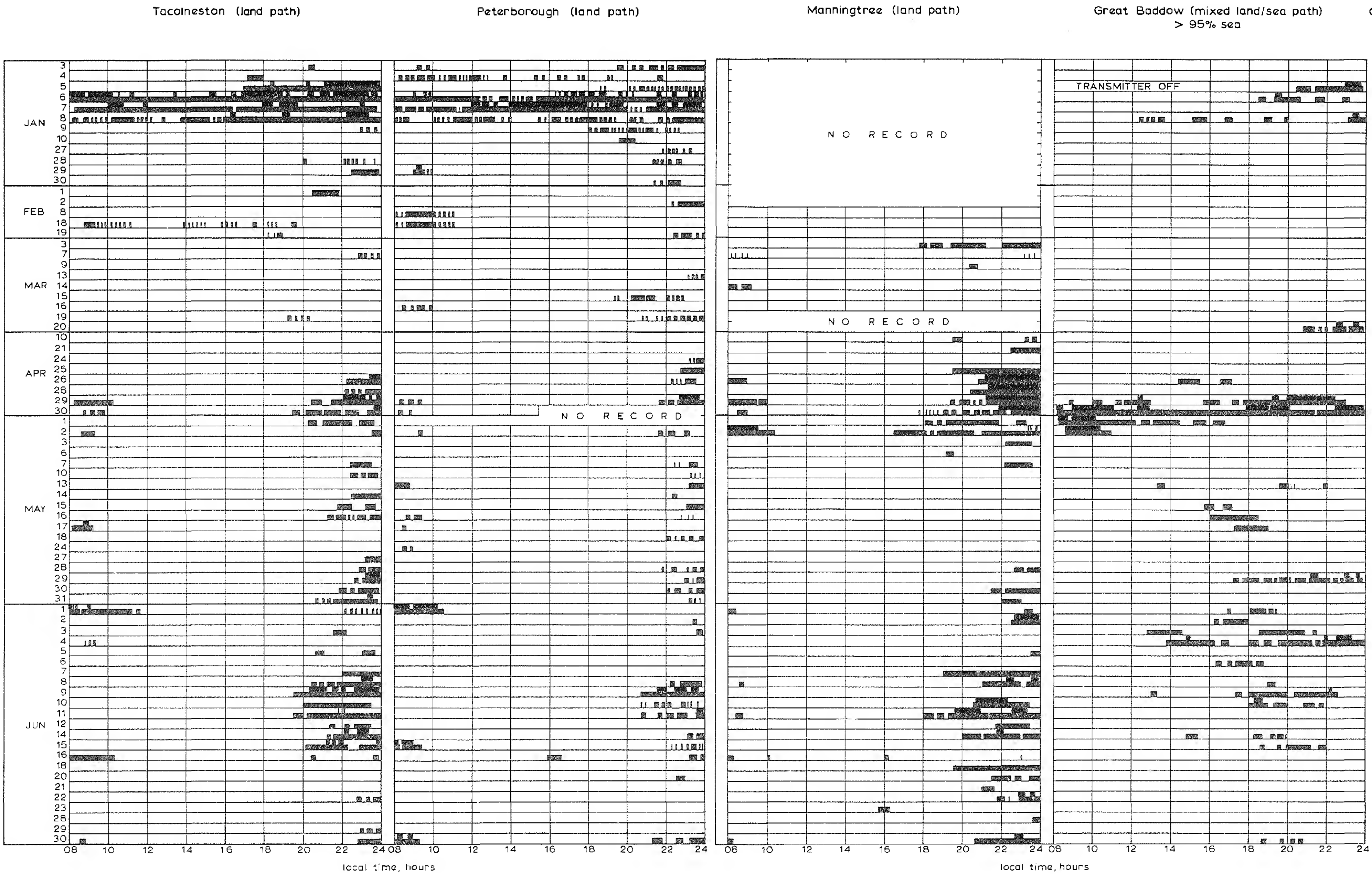
(iv) There is no indication of such diurnal trends occurring on the sea path. In particular the period August 18th to 20th shows high field strengths occurring throughout the daily transmission schedule (see for example Fig. 5(*a*)).

The results in Fig. 4 confirm the results of sections 2.1 and 2.2, which show a diurnal variation of field-strength probabilities over land paths but not over sea paths. Additionally features (ii) and (iii) introduce a further factor in that there appears to be a seasonal trend over land paths, the diurnal variation being least in winter and greatest in summer.

The probable explanation for this phenomenon is as follows: it is well known that abnormal tropospheric propagation is closely associated with the presence of persistent and well-developed anticyclonic conditions. These conditions are characterized by low wind speeds, which enables stratification to occur in the troposphere in the form of temperature inversion layers. It is these inversions which provide the primary mechanism of abnormal propagation. Such anticyclonic conditions are further characterized by extremes of temperature at ground level, these being high in summer and low in winter. The effect of the high daytime summer temperatures is to heat the ground, thereby creating convection currents. The resultant turbulence induced in the troposphere breaks down the stratification consequently reducing the mechanism of abnormal propagation. In winter the ground temperature remains low throughout the day and the stratification is therefore maintained. The sea, having a higher thermal capacity than the land, would not be expected to induce similar turbulence effects due to convection currents during the summer months, and it is therefore not surprising that the seasonal variation is absent for propagation over sea paths.

Although this explanation is undoubtly an over-simplification of the many factors contributing to these diurnal and seasonal variations in propagation characteristics there is little reason to doubt the validity of the basic premises. Although not strictly relevant to the discussion of diurnal or seasonal variations it is of interest to examine the degree of correlation shown in Fig. 4 of the times of occurrence of abnormal propagation over the different transmission paths from Crystal Palace. This correlation is discussed in the Appendix.

* Measurements were made at Manningtree, but the receiving aerial was at 75 m a.g.l. at this time rather than at the standard height of 10 m a.g.l. Nevertheless the records obtained over this period show the same characteristics as the other two land paths.


Tacolneston (land path)
Peterborough (land path)
Manningtree (land path)
Great Baddow (mixed land/sea path) > 95% sea
JAN
FEB
MAR
APR
MAY
JUN
NO RECORD
NO RECORD
NO RECORD
TRANSMITTER OFF
08 10 12 14 16 18 20 22 24
local time, hours

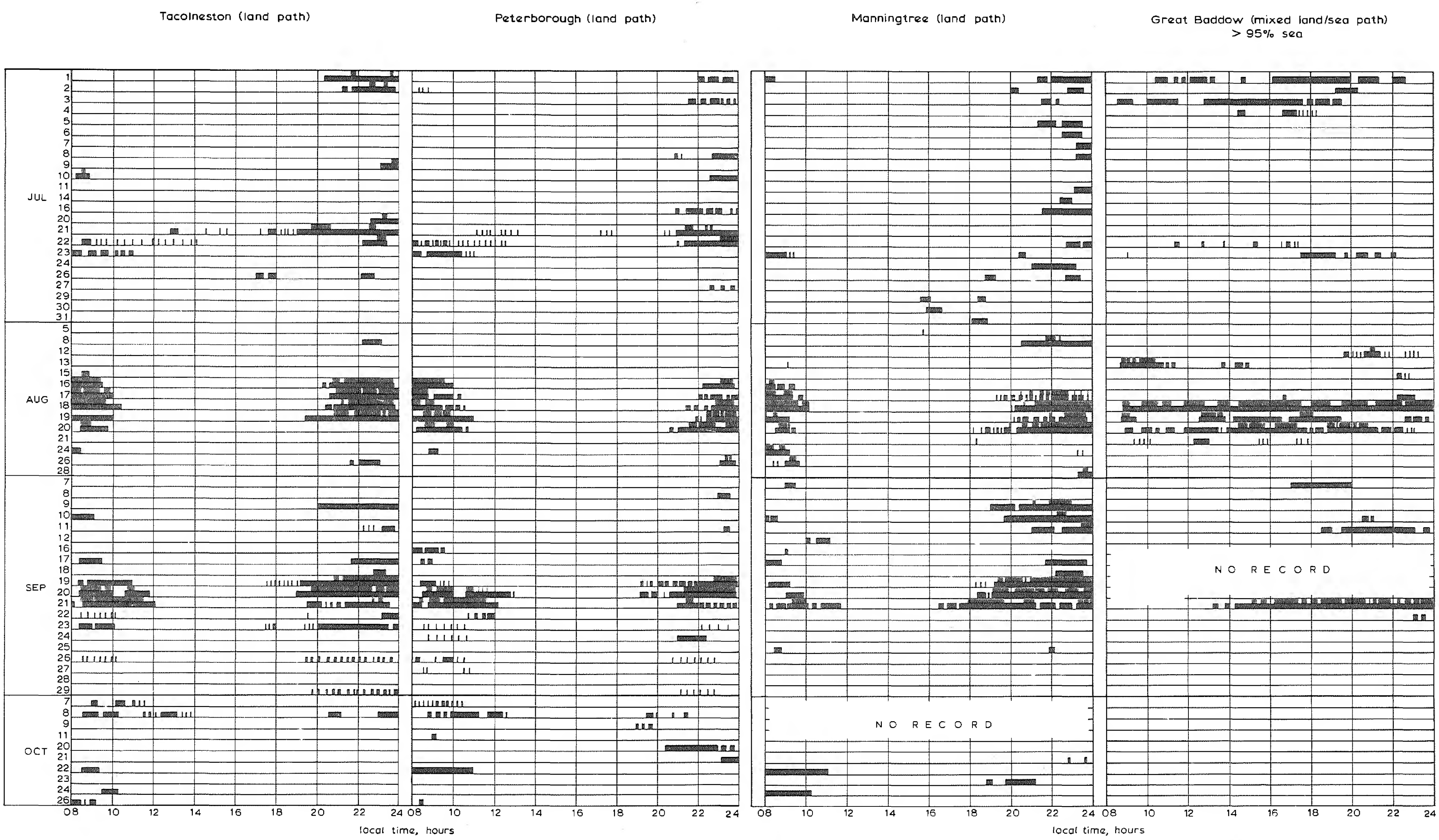



*Fig. 4 - Times of occurrence of exceptional propagation conditions for four transmission paths from January to October 1966*

▪▪▪—— Received field strength greater than that exceeded for 5% of total period of recording

▫▫▫—— Received field strength greater than that exceeded for 1% of total period of recording

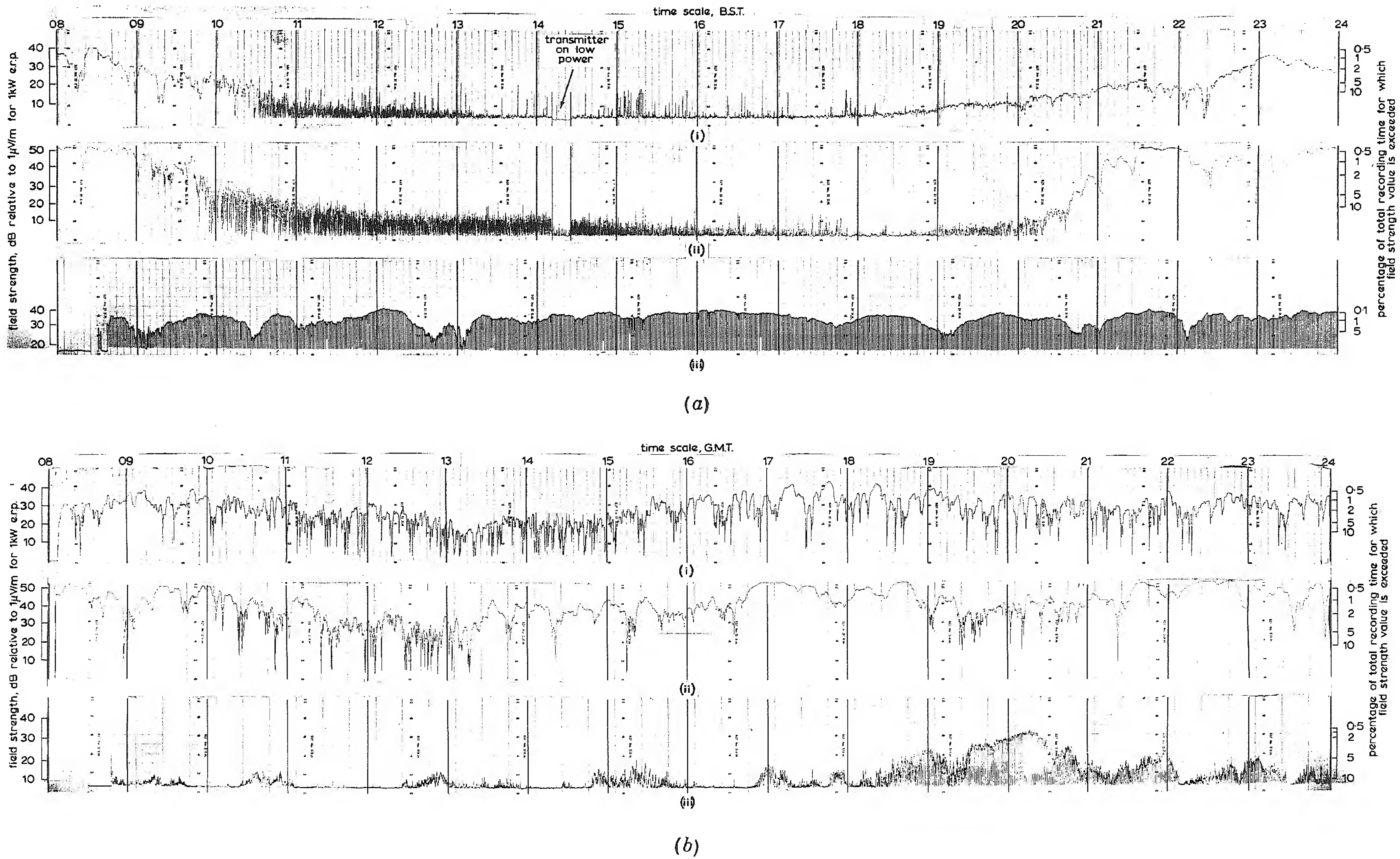



*Fig. 5 - Recordings obtained of abnormal propagation received over three paths in Summer and Winter*

(*a*) Recordings obtained on 18th August 1966 (*b*) Recordings obtained on 6th January 1966

(i) Land Path Crystal Palace to Peterborough (ii) Land Path Crystal Palace to Tacolneston

(iii) 'Sea Path' Scheveningen to Great Baddow

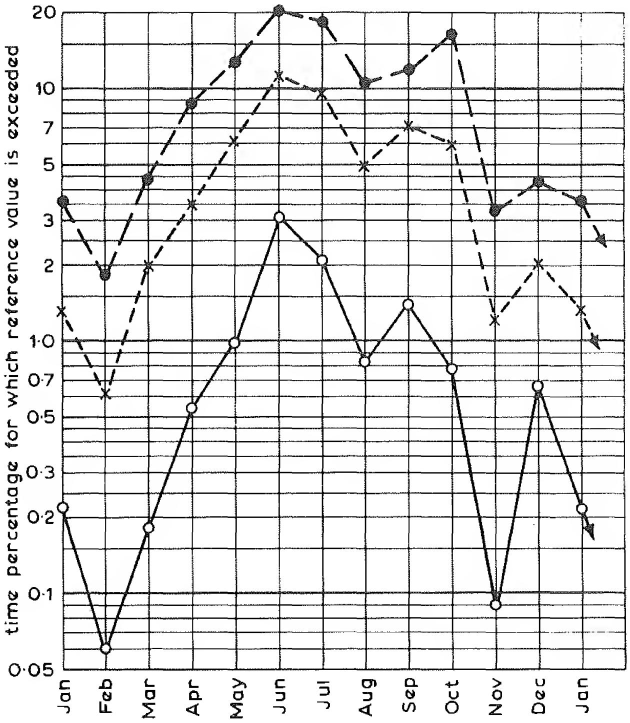



*Fig. 6 - Seasonal variations over sea paths*

—o— Reference value of field strength is that field strength exceeded for 1% of complete yearly period

--x-- Reference value of field strength is that field strength exceeded for 5% of complete yearly period

—●— Reference value of field strength is that field strength exceeded for 10% of complete yearly period

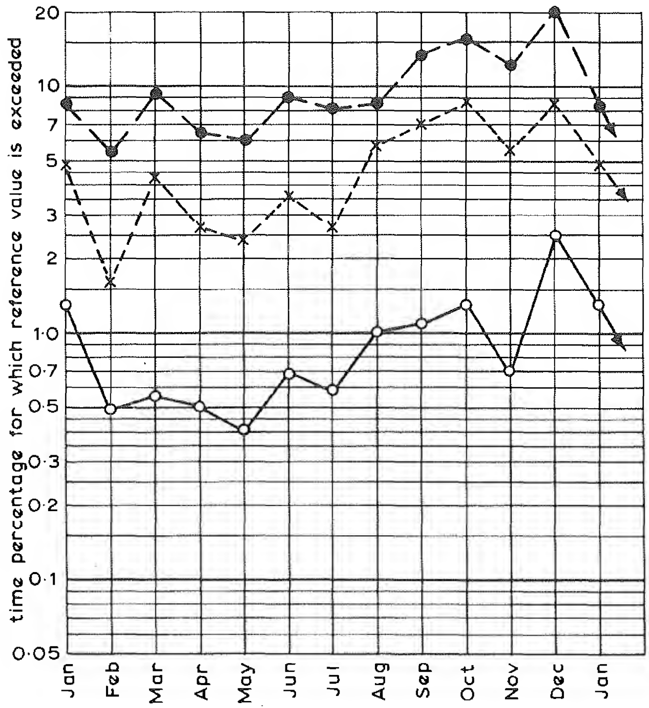



*Fig. 7 - Seasonal variations over land paths*

—o— Reference value of field strength is that field strength exceeded for 1% of complete yearly period

--x-- Reference value of field strength is that field strength exceeded for 5% of complete yearly period

—●— Reference value of field strength is that field strength exceeded for 10% of complete yearly period

## 3. SEASONAL VARIATIONS IN TROPOSPHERIC PROPAGATION CHARACTERISTICS

Hitherto seasonal effects have been referred to only in so far as the diurnal trend may be different in summer and winter. It is however of interest to investigate seasonal effects more fully, particularly since BBC Audience Research Bulletins appear to show that the 'average audience' viewing television in the winter half-year (Sept. to March) exceeds that in the summer (April to August) by some 25%.

In view of the unpredictability of tropospheric meteorological conditions it is virtually useless to attempt any assessment of seasonal trends in propagation characteristics based upon the results of a single measurement programme which might last for one or two years. However BBC Research Department has available the results of a considerable number of measurement programmes, each of 18 to 24 months duration, in both v.h.f. and u.h.f. bands, spanning the period 1954 to 1966. These appear to form a suitable basis for such an examination.

Obviously, if trends are to be obtained from the results of two series of measurements involving different transmission paths and/or different frequencies, we should not average directly either field strengths or fading ranges. Some means of normalization is required for each series and this can be achieved by using the overall field-strength/time-percentage distribution for each series as a reference. Seasonal variations relative to each 18 to 24 month period may be obtained by establishing the values of field strength exceeded for 1%, 5% and 10% of each period and evaluating the corresponding time percentages ($t_1$%, $t_5$%, $t_{10}$%) for each individual month of each measurement programme. For example one propagation experiment may comprise continuous measurements of field strength made at one frequency over a particular transmission path for a period of 24 consecutive months. Suppose the resultant field-strength/time-percentage distribution for this total period to show a field strength of $x$dB($\mu$V/m) to be exceeded for 1% of the time, then the distributions for the 24 individual months may also be examined to determine the time percentages ($t_1$%) for which this field strength of $x$dB($\mu$V/m) is exceeded. These percentages will generally vary from month to month and may also be different for the same month in the two successive years. This experiment will therefore yield two values of $t_1$% for each month of the year.

The results of 25 such experiments over sea paths on the one hand and 31 such experiments over land paths on the other hand, were examined in this way, yielding (for each month of the year), 35 values of $t_1$% for oversea paths and 42 values for overland paths.* The arithmetic means $\overline{t}_1$% of these values were derived for each month of the year for land and for sea paths, as also were the corresponding values $\overline{t}_5$% and $\overline{t}_{10}$%, relating to the 5% and 10% time levels. It may be expected that the number of samples is sufficient for the mean values to have statistical significance, although it must be remembered that only some 13 individual years (1954 to 1966) are involved.

These mean values are plotted, month by month, in Figs. 6 and 7. These figures show seasonal variations as the month by month variation of $\overline{t}_1$%, $\overline{t}_5$% and $\overline{t}_{10}$% relative to the corresponding value averaged over the whole year. Thus, for example, from Fig. 6 we may deduce that although a particular field strength may be exceeded for 1% of the total measurement time when averaged over a whole year, this field strength is exceeded for 3% of the time during the month of June, and for only 0·06% of the time in February. Similarly the field strength exceeded for 5% of the whole year is exceeded for 12% of the time in June and 0·6% of the time in February.

From Figs. 6 and 7 several features may be deduced:-

(a) There appears to be a clearly defined seasonal variation for both overland and oversea paths, the variation being more pronounced for oversea paths.

(b) For oversea paths the probability of occurrence of abnormal propagation is greatest during the summer months (May to September), whereas for overland paths this peak occurs during the autumn (September to December) with a pronounced maximum during December.

It is not proposed to discuss the possible meteorological causes of the seasonal trends indicated in Figs. 6 and 7. It may, however, be pointed out that if the basic meteorological conditions giving rise to high field strengths were to be equally likely to occur at any time of the year, then for overland paths these high field strengths would be expected to occur for a greater proportion of the time in winter than in the other seasons. This is because during the other seasons the times of abnormal propagation are largely confined to the morning and evening periods of the daily transmission schedule. Over sea paths, where no such diurnal effects are in evidence, other factors must account for the observed seasonal variations.

* In this context the results for, say, the month of May comprise all the results obtained in this month for each transmission path investigated, and for the May of every year (between 1954 and 1966), for which measurements are available.

## 4. GENERAL CONCLUSIONS

This investigation has shown there to be a definite diurnal variation in probability of occurrence of abnormal tropospheric propagation. This variation appears to be significant only on overland paths and may be reduced, or absent, in the winter months (see Figs. 4 and 5).

Consideration of the seasonal variations as represented in Fig. 6 indicates that the maximum probability of interference from co-channel transmitters over sea paths occurs in the summer months. These, fortunately, are the months for which Audience Research figures show the lowest 'average audience'. This condition does not apply for interference over land paths, (Fig. 7) but it may be argued that the reduced probability of interference in the first quarter of the year compensates for the greater probability in the fourth quarter.

## 5. ACKNOWLEDGEMENTS

With regard to the current series of propagation measurement described in Section 2.3, thanks are due for the facilities given by the Chief of Research, Marconi Research and Development Laboratories at Great Baddow, and to Mr. G.A. Isted and his staff for their assistance. The assistance given by Engineers-in-Charge and their staffs of the BBC Transmitting Stations at Peterborough and Tacolneston is also gratefully acknowledged.

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## 7. APPENDIX

In the procedure adopted by the BBC for co-channel interference calculations, a coefficient of 0·5 is assumed for correlation in time between the wanted signal and any interfering source. No direct time correlation between individual interfering sources is, however, considered in the calculation for multiple interference. Although it is unlikely that this premise is strictly true it may be considered to introduce a safety factor into the calculation since any positive correlation must reduce the overall time for which interference is significant.

The diagram presented in Fig. 4 affords a convenient means of assessing the degree of correlation which may exist. The results obtained over the Crystal Palace - Peterborough and Crystal Palace - Tacolneston paths provide a particularly useful example since the median and '5%' field strength values for each path are of comparable magnitude. Although these figures represent one transmission received at two sites it may be assumed that correlation for the reciprocal condition (i.e. receiving site at Crystal Palace with more representative aerial heights) will be at least as great.

For the overall period represented in Fig. 4 (January to October 1966) we have:-

% of total transmission time for which field strength at Peterborough exceeds 21 dB ($\mu$V/m) for 1 kW e.r.p. (nominal 5% value*) =3·8%

% of total transmission time for which the field strength at Tacolneston exceeds 25 dB ($\mu$V/m) for 1 kW e.r.p. (nominal 5% value) =4·8%

% of total transmission time for which signals at both sites exceeds specified values simultaneously =2·3%

Now if there were no correlation between the times of occurrence over the two paths the probability of simultaneous occurrence would be given by:-

$$0{\cdot}038 \times 0{\cdot}048 \qquad \text{i.e. } 0{\cdot}18\% \text{ time}$$

It may thus be seen that there is a high degree of correlation between the times of occurrence of high field-strength levels over these paths.

* The discrepancy between the measured percentage (3·8) and the nominal value of 5% arises because the total analysis period from which the specified field strength is derived is not co-incident with the period covered by the diagrams in Fig. 4.

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